

State of the Estuary 2000



Restoration Primer

San Francisco Bay
Sacramento-San Joaquin River Delta
Estuary

San Francisco Estuary Project

A Note on Citations

This report includes a mixture of original unpublished and published research presented at the March 1999 State of the Estuary (SOE) conference (noted as "Author, SOE, 1999" for oral presentations and "Author, SOE Poster, 1999" for posters) with fuller references listed on pp. 73 & 76); and summaries of other research (noted as "Author, Year" with a bibliography on p.76). Some of the secondary, supporting bibliographic references may be absent from page 76 due to a data loss that occurred at press time. To get these references, please email the authors or contacts listed in the section of your interest.

A Note to State of the Estuary Conference Participants

Thank you to all those who responded to our call for updated abstracts after the conference. The San Francisco Estuary Project appreciates your extra work in helping us put together this report (and your patience with its delayed production). Due to budget and space constraints, information from some posters and presentations could not be included in this report, especially if not submitted in digital form as requested soon after the conference. Apologies to any of those who we were not able to include. Information from all posters and presentations can still be found in the original conference abstract book. For a full bibliography of all conference presentations and posters, see page pp.73-75. Updated abstracts on the following (not included in this report) may be obtained by emailing bayariel@earthlink.net: Stress Proteins in Asian clams (Werner); Climate Influence on Diatoms (Starrat); Mercury Discharge Sources (Moran); Water Hyacinths and the Food Web (Toft); Processes Affecting Benthic Flux in Trace Metals (Kuwabara); Legacy of Watershed Management (Mumley); and Land Use & Restoration (Binger). Thank you all again from the San Francisco Estuary Project.

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WHO, WHAT & WHY

This Report describes the current state of the San Francisco Bay-Sacramento-San Joaquin Delta Estuary's environment — waters, wetlands, wildlife, watersheds and the aquatic ecosystem—and provides restoration recommendations.

San Francisco Bay and the Delta combine to form the West Coast's largest estuary, where fresh water from the Sacramento and San Joaquin rivers and watersheds flows out through the Bay and into the Pacific Ocean. In the early 1800s, the Bay covered almost 700 square miles and the Delta's rivers swirled through a vast Byzantine network of 80 atoll-like islands and hundreds of miles of braided channels and marshes. Back then, almost a million fish passed through the Estuary each year and 69 million acre-feet of water crashed down from mountain headwaters toward the sea. But in 1848 the Gold Rush began and hydraulic mining plugged the rivers and bays with more than one billion cubic yards of sediments. Over time, farmers and city builders filled up more than 750 square miles of tidal marsh and engineers built dams to block and store the rush of water from the mountains to the Estuary, and added massive pumps and canals to convey this water to thirsty cities and farms throughout the state.

Today's Estuary encompasses roughly 1,600 square miles, drains more than 40% of the state (60,000 square miles and 47% of the state's total runoff), provides drinking water to 22 million Californians (two-thirds of the state's population) and irrigates 4.5 million acres of farmland. The Estuary also enables the nation's fourth largest metropolitan region to pursue diverse activities, including shipping, fishing, recreation and commerce. Finally, the Estuary hosts a rich diversity of flora and fauna. Two-thirds of the state's salmon and nearly half the birds migrating along the Pacific Flyway pass through the Bay and Delta. Many government, business, environmental and community interests now agree that beneficial use of the Estuary's resources cannot be sustained without large-scale environmental restoration.

This *State of the Estuary 2000* Report summarizes restoration and rehabilitation recommendations drawn from the 29 presentations and 99 posters of the 1999 State of the Estuary Conference and from related research. It also provides some vital statistics about changes in the Estuary's fish and wildlife populations, pollution levels and flows over the past three years, since the 1997 *State of the Estuary* report was published.

The report and conference are all part of the San Francisco Estuary Project's ongoing efforts to implement its *Comprehensive Conservation and Management Plan* (CCMP) for the Bay and Delta and to educate and involve the public in protecting and restoring the Estuary. The S.F. Estuary Project's CCMP is a consensus plan developed cooperatively by over 100 government, private and community interests over a five-year period and completed in 1993. The project is one of 28 such projects working to protect the water quality, natural resources and economic vitality of estuaries across the nation under the U.S. Environmental Protection Agency's National Estuary Program, which was established in 1987 through Section 320 of the amended Clean Water Act. Since its creation in 1987, the Project has held four State of the Estuary conferences and provided numerous publications and forums on topics concerning the Bay-Delta environment.

CONTENTS

Executive Summary.	2
Vital Statistics.	5
Restoration Lessons	17
Creeks	19
Rivers	24
Baylands	40
Bay-Delta	54
Measuring & Modeling Tools	61
Bibliography	73

To find the page number of a specific paper or author, see the conference bibliography. See also note to conference presenters, opposite.

EXECUTIVE SUMMARY

Conference Overview Article
reprinted from *ESTUARY*
newsletter, April 1999

WISING UP ON REHAB

"An ecosystem shaken to its roots," is the way editor Bill Jordan of the University of Wisconsin described the Bay-Delta watershed at the March 1999 State of the Estuary Conference. By the time the conference wound to a close, one thing had become very clear: though the idea of "restoration" has the power to make us all fired up and "dewey-eyed," as Jordan put it, the practice is a far less straightforward endeavor. The government may be spending billions on restoration to soothe the smoldering California water wars, but there's no guarantee that unhitching a few of the shackles binding the estuarine workhorse is going to make it break into a joyful gallop.

The shackles are indeed daunting. First speaker Matt Kondolf of U.C. Berkeley painted a stark picture of damage done to the ecosystem — the dams, reservoirs and levees controlling its spill from the Sierra to the ocean. Only one of nine rivers — the Cosumnes — runs free; only three of dozens of creeks have healthy populations of spring-run Chinook salmon while less healthy salmon venture forth from hatcheries that Kondolf likened to "methadone maintenance programs." Reservoirs in the Sacramento and San Joaquin River basins are so extensive they can now store more water than actually runs off. Real restoration of this system would require removing whole dams from the headwaters and whole cities from the floodplains.

Perhaps that's why conference organizers chose the theme of "rehabilitation," rather than

restoration — a choice second speaker Jordan scolded them for. "Rehabilitation means fitting or refitting something out for use, it's so unspecific it doesn't mean very much," he said, "but everybody knows what restoration means, it means putting something back the way it was, going back to something better."

Whatever the word, putting it back the way it was, using the natural historic landscape and ecological processes as a guide, was the theme of speaker after speaker at the conference. Hydrologist Phil Williams donned an imaginary white coat and diagnosed the Estuary as suffering from many pathological conditions including blocking (dams), narrowing (channelizing) and hardening (levees) of the arteries (rivers), persistent bleeding (exports), flatlining of the rivers (no more peaks and pulses and floods), and anemia (inability to capture sediment). He called the purchase of floodplain lands without making provisions for creating flood flows "cosmetic restoration" and said it was time to retrofit California's "obsolete" water project infrastructure and rethink operation of the dams — many of which operate based on outdated 1940-50s policies and science. "It's time to free ourselves of the legacy of decisions made 60 years ago," he said, calling for serious evaluation of the potential to remove some major dams.

The power of dams and levees to shoot water straight through the Estuary, instead of allowing it to sit around for awhile, was the theme of the following talk, by U.C. Davis' Jeff Mount. Mount said it used to take weeks for water to move through the San Joaquin River system, and now it takes days — largely because the river has been separated from plains where it used to flood, meander and deposit sediments and nutrients. "The best restoration efforts done within the basin will be those that enhance residence times," he said, citing

the productivity of the Yolo Bypass where water now floods 59,000 acres for two weeks instead of a few days, spurring growth of aquatic plants and animals and fattening fish.

When water sits around for awhile, it has more time to seep down and replenish groundwater aquifers and speaker Neil Dubrovsky of the U.S. Geological Survey argued that it's been a mistake to separate management of surface water from groundwater for so long. He reminded the audience that there's three times as much groundwater as surface water, and that the two were once part of an integrated hydrologic system in which groundwater was recharged by infiltration of stream flow and rainfall and in turn supported extensive wetlands along the axis of the Central Valley, as well as sustaining Delta streams during dry months. The valley's aquifers constitute an enormous storage compartment for fresh water (102 million acre feet of usable storage or more than twice the amount stored in reservoirs statewide). Dubrovsky suggested it was time to analyze and confront the long-term costs of groundwater problems caused by overpumping and agricultural drainage — land subsidence and contamination — and to explore storage of water in aquifers rather than new reservoirs, thus recreating the hydraulic connection between water above and below ground.

Next on stage was Stanford's Steve Monismith, who discussed the perils and the promise of using statistical models to predict how Estuary circulation and transport might respond to CALFED's efforts to restore the Delta. Monismith advocated creation of a 21st century replacement for the Bay Model in Sausalito. This new three-dimensional Bay Model 2000 — to be housed in a network of desktop computers — would maintain

accuracy by assimilating real time data from sensors throughout the system and could predict such things as phytoplankton dynamics resulting from creation of new shallow water areas in the Delta.

The creation of too much pavement in the Estuary watershed was Gary Binger's pet peeve. This speaker from the Association of Bay Area Governments described the challenges of getting 101 governments to reduce the amount of impervious surface causing urban runoff pollution, and to protect watersheds and stream corridors. Binger gave the Bay Area an environmental land use report card grade of "C-" — arguing that cities need to do much more to halt land- and water-wasteful sprawl with urban growth boundaries, to cluster new development, to promote urban infill, to increase transit-oriented development, and to stop zoning for jobs without providing housing. The latter has led to longer commutes and more pavement, hence more pollution.

Pollution caused by restoration was the surprise of the next talk, as the U.S. Geological Survey's Sam Luoma reminded the audience that one good thing does not always lead to another. He warned that removing dams or restoring marshes in areas with known deposits of debris from 1800s hydraulic gold mining might worsen the Estuary's already pervasive methyl mercury pollution.

Another potential negative impact from restoration is the increase of opportunities for exotic species to settle in. Disrupted soil, temporarily stripped of shading material, is ideal turf for invading riparian plants like *Arundo donax* (a habitat- and water-guzzling species commonly known as the "plant from hell"); likewise, salt ponds recently opened to the tides and newly created wetlands offer a blank slate for Atlantic cordgrass

— a fast-spreading wetland plant currently making a folly out of many well-intentioned restoration efforts. According to U.C. Berkeley's Tom Dudley, the "build it and they will come" mentality must be tempered with planning to prevent unwanted vegetation. He also pointed out that the "stable hydrology" of our highly controlled water system reduces biodiversity and promotes invasions.

One of the strongholds of native biodiversity, at least in terms of fish, is Bay creeks, said speaker Rob Leidy of U.S. EPA. Compared to Central Valley creeks, Bay creeks have more diverse and healthy assemblages of native fish. Indeed native species dominated 75% of sites sampled by Leidy in 30 watersheds. Reasons for good native fish survival around the Bay may include fewer dams, diversions and reservoirs (major sources of exotics), less distance to the open ocean for migrating anadromous species, and the salt water at creek mouths — preventing movement of freshwater species and invaders between drainages. "These are all strong arguments for focusing restoration on Bay streams," said Leidy.

Restoration aimed at getting the most endangered fish, animals and plants back on their gills, feet and roots pervaded an information-packed panel on Day 2 of the conference. First up were fish. According to U.C. Davis' Peter Moyle, who reviewed the status of several declining native species, Delta smelt show no sign of recovery and nobody understands what's going on with green sturgeon. Numbers of splittail, salmon, longfin smelt and two other native fishes of concern have grown in the last five years as a result of an unusual series of wet years and the accompanying increased river flows. A return of the drought and high rates of diversion will likely cause their numbers to plummet again, however. "Nature

has cooperated ever since the Bay-Delta Accord, and bought us some time. We need to make some serious commitments to conservation before the next drought," said Moyle. To help the fish, Moyle called for more and better floodplains, more natural hydrological regimes, improved access to upstream habitats, and prevention of further invasions by exotic species.

Prevention won't do much for natives of the Estuary's muddy and rocky bottom, however. According to Cal Fish & Game's Kathy Hieb, up to 90% of the benthic community is comprised of exotic species in many places, and no amount of habitat restoration can bring back the natives. In recent years, native zooplankton continued their decline dating back to the 1980s, she said, but Bay shrimp are on the rebound in part due to increased flows that aid shrimp migration and enhance nursery habitat. The ups and downs were nothing new to Hieb, who completed her talk by throwing up her hands and saying "There's no doubt that variability is the essence of the Estuary."

Owls and frogs could use a little more of that variability said the next speaker, at least in terms of habitats. Three quarters of the uplands once adjacent to the Bayshore have been farmed, grazed, logged, developed or otherwise destroyed, said San Jose State's Lynne Trulio, and today's levees now create a "hard edge around many wetlands, leaving virtually no transition to remaining uplands." Trulio zeroed in on the importance of this transition zone for the many birds, amphibians and terrestrial species (85% of special status species) that cross back and forth over the wetland/upland edge in search of food and refuge. "The hydrological situation on these transitional habitats is very complex and difficult to replicate. The problem is, we have almost no moist grassland, no vernal

pools left to copy," she said.

The hard edge of many wetland restoration sites doesn't do much for floristic diversity either, according to speaker Brenda Grewell of U.C. Davis. As slide after slide of rare petals and foliage graced the screen, Grewell reminded the audience that plants offer both ecological and aesthetic benefits. Habitat degradation and fragmentation, and intruding exotic flora, have diminished many emergent marsh plant communities, and decimated species such as soft-haired birds beak, Suisun thistle and Mason's lilaeopsis. According to Grewell, restoration opportunities that "link tidal marshes to alluvial soils, seeps and drainages should be a high priority. The current tendency to create tidal marshes as indented pockets within levee systems, separated from the historic margins of the Estuary, will not support historic floristic diversity."

Next speaker Gary Page of the Point Reyes Bird Observatory warned that although tidal marsh and mudflat restoration in the Bay will help many birds, converting salt ponds to this end may not. "We can't turn back the clock for the Bay. Conversion of man-made salt ponds will have negative consequences for many waterbirds, birds that have no place else to go," said Page.

Far upstream where the wide shallows of salt ponds and Bay waters narrow into nine rivers and myriad tributaries, restoration efforts are often short-lived, said speaker Scott McBain of McBain and Trush. Here high flows are quick to damage or destroy the kind of patchwork attempts to restore individual gravel beds or river banks that have occurred without attention to the system as a whole. To better guide restoration, McBain listed ten attributes of healthy, alluvial, low-gradient, gravel-bed rivers in the Central Valley, among them variable stream flows; frequent movement of riffles and bars by moderate floods; periodic channel

migration; access to a functional floodplain; and sediment transport at approximately the same rate as delivered by the watershed. These simple, quantifiable attributes evoke the historic fluvial processes that underpin the river system, according to McBain. Based on these attributes, McBain's recommendations for river rehabilitation ranged from creating more varied stream flows and establishing continuous riparian floodways to increasing coarse and reducing fine sediment supplies and storage.

Later, Joy Zedler from the University of Wisconsin, and several other speakers, described the critical follow-up task of monitoring the results of restoration efforts. Zedler's case in point was a 300-acre San Diego mitigation project called Sweetwater Marsh. In her evaluation of project success, Zedler looked at the degree to which compliance criteria had been met for three endangered species damaged by the development. Using remote sensing and satellite imagery as tools, Zedler examined habitat development over time and found that criteria for two species — the California least tern and salt marsh birds beak — had been met. Habitat for the light-footed clapper rail, however, had serious short-comings, namely coarse soil, low nutrient supplies, short vegetation, scale insect outbreaks and inadequate nesting habitat.

According to Zedler, lessons learned from the San Diego project pinpoint five ecosystem components that should not be ignored in restoration: anthropod predators (there were no beetles to prey on the scale insects); plant canopy structure; soil structure; soil nutrients and site-landscape interactions.

Another follow-up effort was described by Charles Simenstad from the University of Washington, who compared several different restoration projects of different ages in the

Pacific Northwest to local control sites. Looking for a possible correlation between project age and fish utilization, he found that the numbers of juvenile Pacific salmon and a prominent sculpin generally increased in the older marshes.

Simenstad felt that although the promise of restoring tidal marsh ecosystems has increased over the years, efforts still suffer from the following pitfalls: "functional forcing" (restoring only one or two functions or habitats rather than a whole multi-functional ecosystem); "demand for instant gratification," (expecting marshes to mature in far less time than natural processes allow, and intervening to make things speed up, which is often counterproductive); and "maladaptive monitoring" (monitoring response without exploring the underlying ecological processes at work in the system.

As the conference progressed, speakers touched on myriad other topics ranging from restoring Delta islands, managing stormwater and working with wildlife-refuge neighbors to developing publicly palatable indicators of restoration success and coming to scientific consensus on ecosystem goals.

As engineer Jeff Haltiner of Philip Williams & Associates put it in the waning hours of the conference: "It's nice to be involved in the restoration movement, it's kind of messianic, religious... When it gets boring and mundane, that will be when it's successful, because it will be ingrained in the culture of the country."

-Ariel Rubissow Okamoto

V I T A L S T A T I S T I C S
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PERSPECTIVE

Historical Changes to the Bay-Delta Watershed:

Implications for Restoration

G. Mathias Kondolf
University of California, Berkeley

Over the last century and a half, the watershed of the San Francisco Bay-Delta has been altered to an extent not commonly appreciated. Populations of native fishes (including an estimated 2-3 million Chinook salmon) that formerly inhabited the system have declined, with many races extinct or nearly so. Overfishing and competition from introduced species have been important factors in the declines. Moreover, the geomorphic, hydrologic and ecological processes in the watershed that formerly supported these native fish species have been fundamentally changed by dams, diversions, groundwater pumping, conversion and filling of floodplain and intertidal wetlands, gold and gravel mining, levees, artificial bank protection, pollution, and land-use changes in the watersheds draining to the rivers, Delta, and Estuary.

Reservoir storage capacity in the Sacramento-San Joaquin system now totals 30 million acre-feet, with storage equivalent to over 80% of the runoff in the Sacramento River basin and nearly 140% of the San Joaquin River basin runoff. As a result, frequent floods (important for maintaining channel form and habitat) have been eliminated or drastically reduced on many rivers. As documented by the Bay Institute, tidal wetlands in the San Francisco and Suisun Bays have been reduced to only 8% of their former extent. Intertidal wetlands in the Delta have been diked off so thoroughly that of the 400,000 acres that existed in 1850, only 8,000 remain: only 2% of their original extent. Similarly, 90% of the riparian forest and riparian wetlands of the Sacramento Valley have been cleared, filled, or otherwise eliminated (Bay Institute 1998).

It is essential that we understand the nature and extent of these changes to develop restoration goals and to understand constraints upon what we can realistically achieve, even in a massive restoration program (Kondolf and Larson 1995). For example, we understand that extensive flooding

was an important process in maintaining habitat for salmon and other native fish, but we cannot realistically move large cities from the floodplain, nor is it likely that we will remove most existing dams. However, it may be possible to restore floodplain flooding along some rivers and streams, permitting natural processes to shape channel and floodplain habitats. Thus, we should prioritize acquisition of land or flooding/erosion easements along rivers that still flood (i.e., rivers that have not been so dammed that they no longer have high flows). Restoration of floodplain functions in these reaches can also reduce flooding pressure elsewhere (Healey et al. 1998).

To be effective and sustainable, restoration must be based on a real understanding of geomorphic and ecological processes, which can inform restoration goals and choice of implementation strategy. Recognizing that uncertainty is unavoidable in light of our limited understanding of the functioning of the system, an adaptive management approach has been adopted by the CALFED ecosystem restoration program, emphasizing that restoration actions can be taken that serve to increase our understanding of the system's responses (Healey et al. 1998) (Kondolf, SOE, 1999).

► MORE INFO?

www.ced.berkeley.edu/landscape/kondolf



FLOW

Recent Inflows

Normal or above normal rainfall has meant improved Delta inflows in recent years. Inflows to the Delta and Estuary were 39.8 million acre feet (MAF) in water-year 1997 (October 1,1996 - September 30,1997),48.5 MAF in 1998 and 28.3 MAF in 1999. Delta outflows were 33.7 MAF in 1997,43.5 in 1998 and 22.4 in 1999 (DWR).

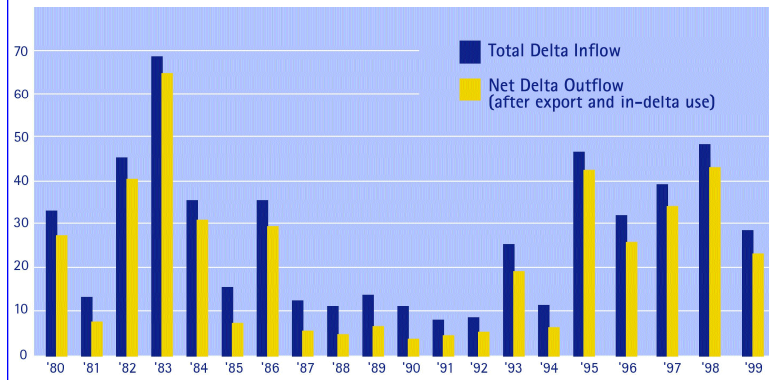
➤ MORE INFO? dfriend@water.ca.gov

Diversions for Beneficial Use

Water is diverted both within the Delta and upstream in the Estuary's watersheds to irrigate farmland and supply cities. In-Delta exports have largely remained within the range of 4 to 6 MAF per year since 1974,but the percent of Delta inflow diverted can vary widely from year to year. In water-year 1997,5.1 MAF were diverted, 4.8 MAF in 1998 and 5 in 1999. The mean percentages of total Delta inflows diverted were 13% in 1997, 10% in 1998 and 18% in 1999 (DWR).

➤ MORE INFO? dfriend@water.ca.gov

Freshwater Flows to the San Francisco Estuary, 1980-96 in millions of acre feet



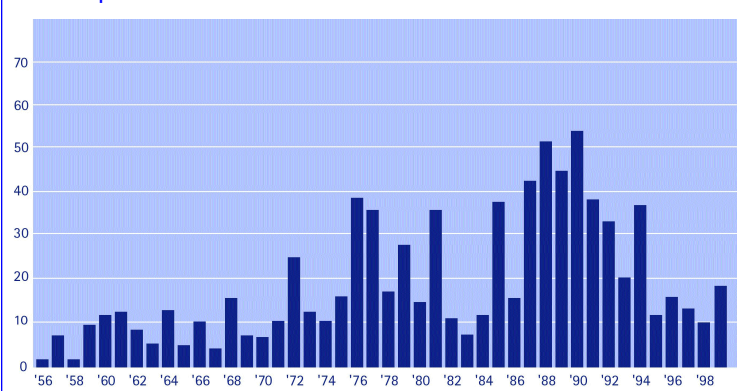
Source: DWR

Water Recycling

Recycled water can be used to meet many of the needs of cities, industries and agriculture, helping to reduce demand on the Estuary's limited water supply. Much more information documenting recycled water use was available for the last *State of the Estuary* report (1993-1998) than for the most recent period covered by this report. Experts say conditions have been wet enough in recent years to dampen enthusiasm for recycling projects. In general,however, Southern California remains far ahead of the Bay Area in water recycling efforts. But 25 Bay Area communities currently have or plan water recycling projects. The Bay Area Regional Water Recycling Program's Master Plan calls for recycling 125,000 acre-feet of water per year in the Bay Area by 2010 and about 240,000 af/year by 2025 to help create a reliable, drought-proof water supply.

➤ MORE INFO? www.recyclewater.com.

Amount of Inflow Diverted, 1956-99
Mean percent of inflow diverted



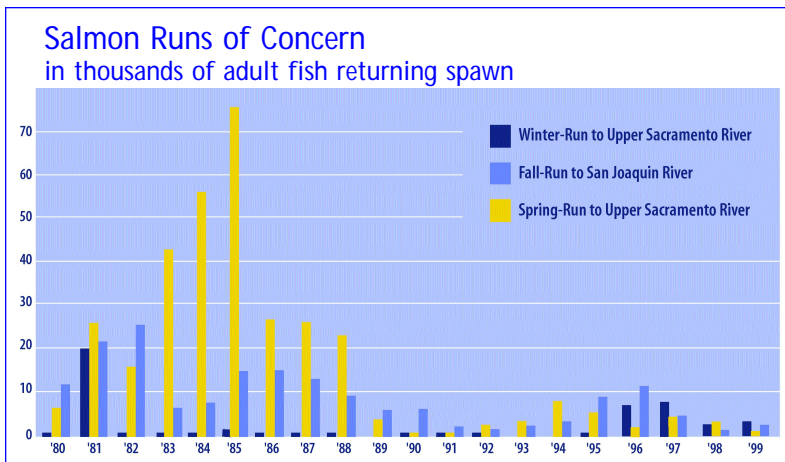
Source: DWR

FISH

Central Valley Salmon

Most populations of Central Valley Chinook salmon seem to be holding relatively steady, with increases for several protected runs. Central Valley salmon occur in four discrete runs — winter-run, spring-run, fall-run and late fall-run (run refers to the season in which adults return to their native streams to spawn). The winter-run Chinook, with the lowest population, has been listed as both a state and federal endangered species since 1994. Although the 1997 return of winter-run was only 841, the population rebounded somewhat to 2,612 in 1998 and 3,208 in 1999, the highest return since 1985. The next most sensitive stock, the spring-run, was state listed as a threatened species in 1998 and federally listed in 1999. The spring-run population jumped from a five-year low of 5,312 in 1997 to 31,594 (the highest on record), then fell to 10,134 in 1999. Sacramento fall-run are the most abundant Chinook stock, with 308,674 returning in 1999. The 1999 San Joaquin fall-run return of 24,459 was also above the 1967 to 1991 average annual return of 21,000. The "late" fall-run (distinct from fall-run) Central Valley Chinook population was 4,578 in 1997, 12,796 in 1998 and 8,683 in 1999 (Kano, Pers.Comm., 2000).

➤ MORE INFO? bkano@dfg.ca.gov.



Source: CDFG

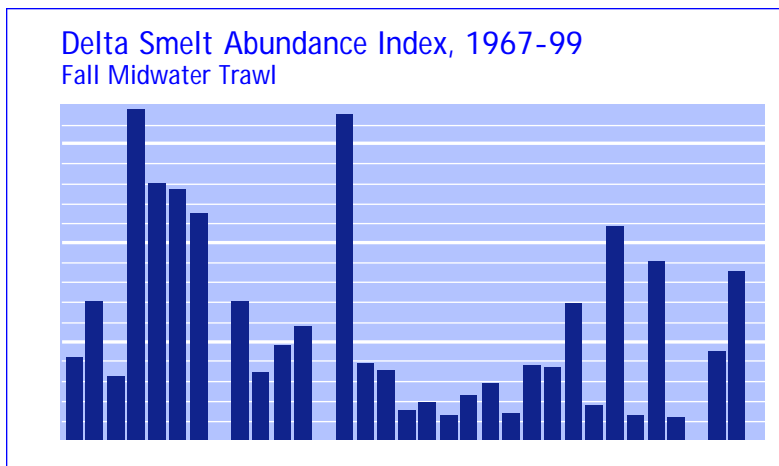
Delta Smelt

The Delta smelt, a 2-3 inch-long, translucent fish with a silvery blue sheen, was listed as a state and federal threatened species in 1993. Historically one of the most common species in the Estuary, the population declined dramatically in the early 1980s. Delta smelt are considered environmentally sensitive because they typically live for one year, have a limited diet, and reside primarily in the interface between salt and fresh water. In addition, females produce only 1,000 to 3,000 eggs, and the planktonic larvae have a low survival rate. Possible reasons for the Delta smelt's decline include reductions in outflow, high outflows (which push them too far down the Estuary), entrainment losses at water diversions, changes in food type and abundance, toxic substances, disease, competition, predation and loss of genetic integrity. The 1998 Fall Midwinter Trawl index, 420, was the highest in three years, and the 1999

Summer Townet index, 11.9, was the highest since 1994, although it was still below a pre-decline average of 20.4. The 1999 fall midwater trawl index was 864, the third highest in 19 years. In the spring of 1999, delta smelt spawned primarily in the Delta and remained there for several weeks, causing high entrainment levels at the State Water Project and the Central Valley Project and reduced water exports at both facilities for over a month (McIntire, Pers. Comm., 2000; Rockriver, Pers.Comm., 2000).

➤ MORE INFO?

8mcintir@delta.dfg.ca.gov



Source: CDFG

Longfin Smelt

Experts predicted a large longfin smelt population in 1997 due to very good recruitment in 1995 and extremely high outflow in winter 1997, when the 1995 year class spawned. However, longfin smelt abundance, as measured by the CDFG fall midwater trawl survey, only reached an index of 676, just slightly higher than indices during the 1987-1992 drought. This severe decline led to speculation that many recruits had washed out to and reared in the Gulf of the Farallones. However, age-1 longfin smelt indices in 1998 were also very low, suggesting poor survival for the 1997 year-class. In 1998, longfin smelt abundance increased substantially to an index of 6,658, mostly comprised of young-of-the-year. The 1998 progeny resulted from 1996 year class spawners, the first even-year recruits from a post-drought wet year. Historically, strong year classes alternated years and were a function of outflow during the early larval period. Poorer than expected longfin smelt abundance in 1997, together with good flows in 1996 and better flows in 1998 allowed even-year classes to build on one another and become dominant (Baxter, Pers.Comm.,2000).

► MORE INFO? rbaxter@delta.dfg.ca.gov

Splittail

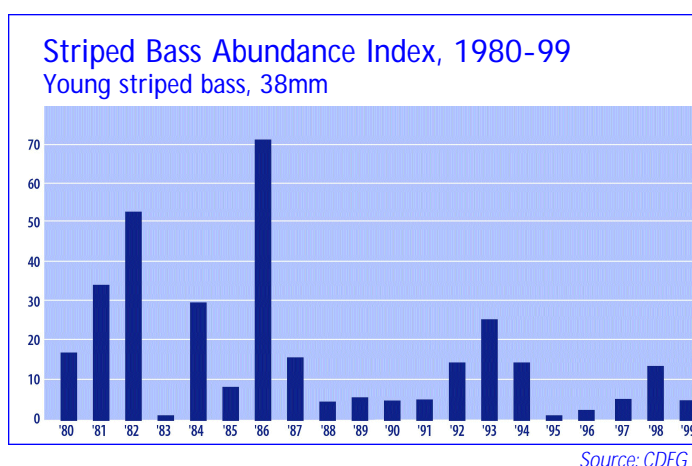
The Sacramento splittail appears to have benefited from the recent series of wet years (Moyle, SOE, 1999). Populations of the silvery-gold minnow, found only in Central Valley rivers and the Delta, had declined sharply in recent years as a result of drought, dams and diversions reducing access to spawning habitat. The splittail was listed as threatened under the federal Endangered Species Act in early February 1999. Splittail abundance in 1997 was poor (CDFG fall midwater trawl survey index = 1.1), contrary to predictions. Though dramatic flooding occurred in January 1997, the lack of subsequent rains resulted in dry conditions during the March-April peak spawning period. In contrast, high and persistent outflows in 1998 led to a record high fall midwater trawl survey total index of 282. Young-of-the-year (YOY) made up 85% of the total index. Though not record indices, YOY indices from the Delta Outflow-San Francisco Bay Study midwater and otter trawls reached levels comparable to 1995, again indicating strong recruitment for 1998 (Baxter, Pers.Comm.,2000).

► MORE INFO? rbaxter@delta.dfg.ca.gov

Commercial Fisheries

Although the spawning biomass of Pacific herring — by far the Bay's largest commercial fishery — was the third highest on record in 1996-1997, it plunged to 20,000 tons in 1997-1998 due to low ocean productivity attributed to 1997's El Niño, and has not recovered. The spawning biomass in 1998-1999 was 39,500 tons, and despite good ocean productivity, preliminary indicators are that the 1999-2000 spawning biomass will be below the long-term average, which stands at 54,929 since 1978-1979 (Watters, Pers.Comm., 2000).

► MORE INFO? dwatters@dfg2.ca.gov



Striped Bass

The population of striped bass, an important sport fishing species, shows little sign of improvement. In 1999 the indices for both the mid-summer townet survey and the fall midwater trawl survey indicated that young-of-the-year striped bass abundance is considerably lower than in the 1970s and early 1980s. Before 1995, high indices were generally associated with wet years and low indices with dry years. However, since 1995, both indices have been the lowest on record even though these were wet years. The 1999 townet survey index was 2.2, making the fifth consecutive year that the index has been below 10. The 1999 fall midwater trawl index of 541 was only 44% of the 1998 index of 1,224, but similar to the years 1995-1997, when the index varied from 392 to 568. Prior to 1995, only five other years (all dry or critically dry) had fall indices below 1,000 (Gartz, Pers. Comm.,2000).

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See also page 34 for more information on endangered fish.

INVASIVE SPECIES

Green Crabs

The green crab (*Carcinus maenas*) was first found in South San Francisco Bay in the early 1990s, and has spread north at least as far as the Carquinez Strait. Its distribution is limited by salinity: crabs have been collected from water ranging from 7.5-31 parts per thousand (ppt) salt to water, but few have been collected from water with less than 10 ppt. On the west coast, green crabs are now found as far north as British Columbia (Hieb, Pers.Comm., 2000). In contrast to its wide native range along the Atlantic coast of Europe, in western North America the green crab is restricted to low energy, soft substrate habitats.

In a nine-year study of green crabs in Bodega Bay, Grosholz, et al. found that in contrast to their slow growth rates in Europe, green crabs grew rapidly and reached sexual maturity in their first year. Over the course of the nine-year study, the green crab significantly reduced the abundance of 20 invertebrate species, and within just three years of being introduced, reduced densities of native clams and native shore crabs by 5-10%, including that of the shore crab *Hemigrapsus oregonensis*, a common inhabitant of the lower South San Francisco Bay. The study found no "bottom-up" effects on the food web that would impact shorebirds; however, such effects may occur as the geographic range and local effects of the green crab increase (Grosholz, et al. 2000).

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Mitten Crab Catch

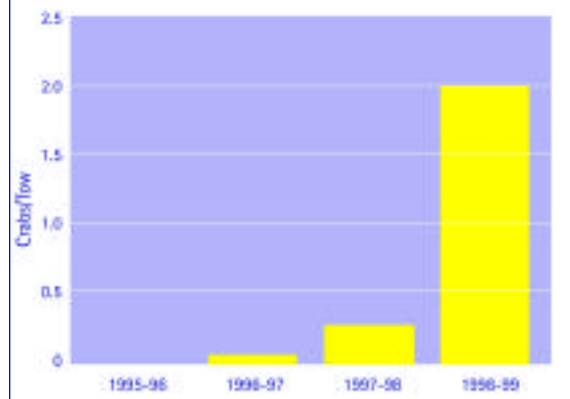


Figure 1. Annual (October-March) catch per tow of adult Chinese mitten crabs from CDFG's San Francisco Bay Study otter trawl survey, 1995-96 to 1997-98. All female crabs >34 mm carapace width (CW) and male crabs >39 mm CW were considered to be adult. Source: CDFG

Chinese Mitten Crabs

The Chinese mitten crab (*Eriocheir sinensis*) was introduced to South San Francisco Bay in the late 1980s or early 1990s; the 1990s saw a rapid increase in its population and expansion of its distribution. By 1998, the mitten crab was widely distributed in the Sacramento-San Joaquin Delta and the Central Valley. In 1999, the population of adult crabs decreased somewhat, and distribution was more restricted than in 1998, especially in the San Joaquin River. Although initially the mitten crab population in California increased exponentially, it is expected to eventually decrease and remain at low or stable levels for some time — in the "boom and bust" style of many introduced species (Hieb, Pers.Comm., 2000).

Migrating adult crabs have interfered with fish salvage activities at pumping facilities in the south delta. In fall 1996, the federal water project collect-

Bay-Delta Mitten Crab Spread

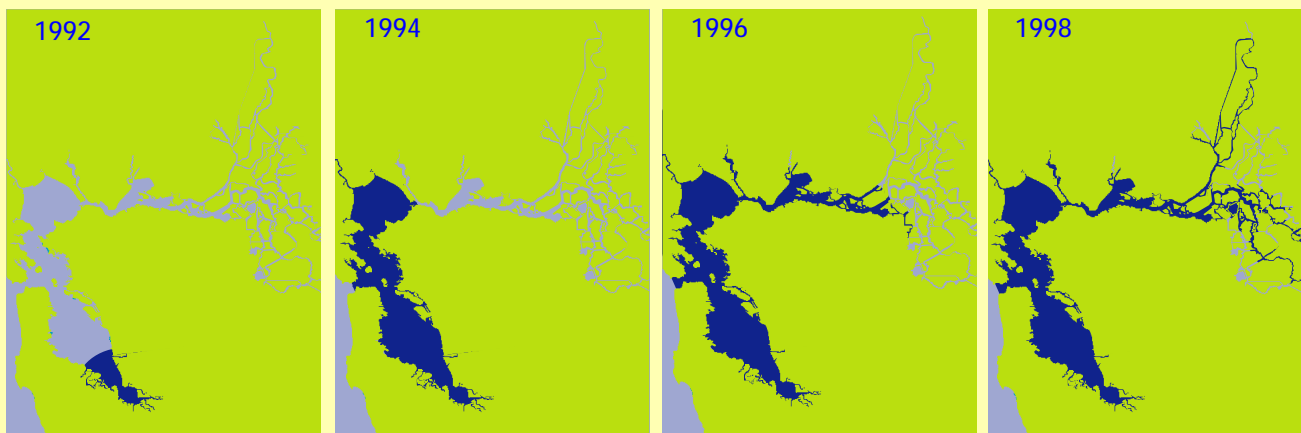


Figure 2. Distribution of the Chinese mitten crab in the San Francisco Estuary and its watershed, 1992, 1994, 1996, and 1998. Solid blue area or lines indicates presence of the crab. Source: CDFG

ed less than 100 crabs at their fish salvage facility. In fall 1997, they collected approximately 30,000 crabs; in fall 1998, at least 775,000 crabs; and in fall 1999, approximately 90,000 crabs.

Mitten crabs also steal bait from sport anglers and bay shrimp from commercial trawl nets, and clog PG&E power plant cooling water systems in the western delta. The crab's burrowing is thought to weaken levees and banks, but no damage attributable to the crab has been confirmed. A National Management Plan for mitten crabs has been submitted to the Aquatic Nuisance Species Task Force.

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Pike

Northern pike, native to Canada and the Midwest, were illegally planted in the 85,000-acre-foot Lake Davis reservoir around 10 years ago. In 1997, the state Department of Fish and Game treated the lake with Rotenone to try to prevent the voracious fish from escaping into the Sacramento River and eating endangered salmon, but the treatment temporarily compromised local water supplies and an important local fishery. In May 1999, the pike reappeared. Since then, biologists have pulled over 250 pike from the lake, in an effort to prevent the population explosion seen between 1994 and 1997. After fish surveys revealed that 95% of the pike were inhabiting Mosquito Slough, a shallow weedy channel leading into the lake, a 250-foot wide, 20-foot deep net was installed across the mouth of the slough to trap the pike and prevent them from entering the lake (Martarano, Pers. Comm., 2000). The pike have not been found outside of Lake Davis during the last few years (Moyle, Pers. Comm., 1999). A Lake Davis Coalition was formed and released a management plan in February 2000 recommending trying physical barriers, electric shocks, underwater explosions, and even fishing derbies to control the pike.

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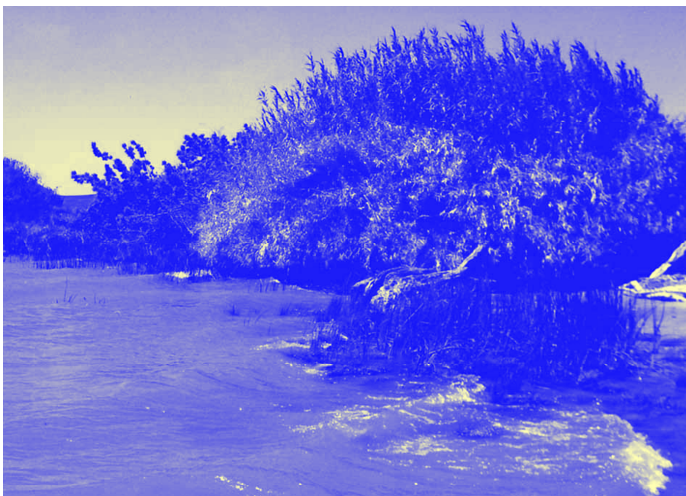
Asian Clams

The Asian clam *Potamocorbula amurensis* has continued to be the dominant benthic organism in the North Bay and is also dominant in the Bay's southern extreme during most years. The return of freshwater flows has resulted in a seasonal decline of the bivalve throughout the North Bay in winter, followed by peaks in density after reproduction in spring and fall. A substantial increase in phytoplankton biomass was seen in spring 1998 in central San Pablo Bay. The only benthic station that is routinely sampled in San Pablo Bay, DWR's station D41A, shows the phytoplankton bloom occurred during the annual drop of *P. amurensis*, thus supporting the supposition that declines in phytoplankton are a result of overgrazing by *P. amurensis* (Thompson, Pers. Comm., 2000).

Giant Reed

Giant reed (*Arundo donax*) was originally introduced into California by the Spanish in the late 1800s for erosion control along drainage canals, and since then this "plant from hell" has become a huge problem along riparian areas around the Bay. The reed spreads when pieces of the plant break off and wash downstream. The pieces—from either the stalk or roots—can establish themselves wherever they are deposited. The reed guzzles water and can smother native riparian vegetation. It is also highly flammable. In 1997, it had been spotted in the Russian River, Napa River, Sonoma Creek, and San Pedro Creek. Just a few years later, it can be found from Sacramento tributaries to small urban streams throughout the Estuary. Eradication and education programs are underway.

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Courtesy Ron Unger

Shimofuri Goby

The shimofuri goby (*Tridentiger bifasciatus*) is a recent invader of the Estuary, and probably arrived in ballast water. The goby was first collected in 1985 in Suisun Marsh and has spread rapidly throughout the Estuary. In Suisun Marsh, the goby spawns repeatedly from March through September, typically depositing 9,000 – 19,000 adhesive eggs on a hard, protected surface. The male goby guards the eggs until they hatch, which can take five to ten days depending on water temperature. Experiments show that the shimofuri goby can tolerate a wide range of temperatures and salinities, which means it is capable of expanding its range into that of the endangered tidewater goby (*Eucyclogobius newberryi*). In the laboratory, shimofuri gobies are aggressive toward tidewater and yellowfin gobies (Matern, SOE poster, 1999).

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For more information on invasives see pp. 54-55.

WETLANDS & WILDLIFE

Wetlands

Only 3-4% of the Bay-Delta's historic wetlands remain intact today. Fewer wetlands and riparian zones have been protected through acquisition since 1996 than in the prior three year period, falling from 18,677 acres in 1996 to 10,983 in March 1999. During the earlier period the vast majority of reported acquisitions were baylands (namely the unusually big purchase of almost 10,000 acres of North bay salt ponds),whereas the more recent period included much larger acreages of riparian zones and floodplain (6,106 acres in the San Joaquin River Wildlife Refuge alone). Acres protected by perpetual conservation easements over private lands in the Central Valley and Suisun Marsh grew from 67,292 to 75,000 acres between 1996 and 1999.

On the restoration front, the number of acres actually restored or enhanced grew from at least 8,137 acres in 1996 to at least 13,656 acres of wetlands in March 1999 (note:acquisition and restoration acreages overlap). The number of restoration projects in the planning stages, many with no guarantee of construction funding, also swelled, from at least 12,693 acres in 1996 to 19,109 acres in March 1999. Where most projects might have been undertaken as mitigation for development of wetlands in the past, the vast majority of current projects are aimed at the health of the ecosystem. The acreage of wetlands restored outpaced that lost — see p. 67. Finally, programs providing incentives to individual landowners to flood their land for seasonal waterfowl and wetlands continued to grow — enhancing or restoring over 90,000 acres as of 1999 —but did not keep up with demand (the owners of at least 47,000 acres still want to sign up) (Appendix A, SFEP, 1999).

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California Clapper Rail

While numbers of the endangered California Clapper Rail (*Rallus longirostris obsoletus*) had dropped as low as 300-500 birds by 1991, recent surveys indicate the rail's Bay population may be close to 1,200 and fairly evenly divided between the North and South Bays. However, heavy rains in the winter of 1997-1998 may have caused some declines in the North Bay, as residual high water, particularly along the North San Pablo Bayshore impacted nesting success (Albertson and Evens 1998). See also p. 46.

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Least Terns

While endangered least terns continue to nest at the Alameda Naval Air Station, re-use of the station may not bode well for the terns, with human disturbance and non-native predators on the rise. Although the number of pairs of terns using the base remains stable, the number of successful fledglings has decreased by a third since 1997. Further north, the number of terns at the Southern Power (formerly PG & E) cooling ponds in Pittsburgh has tripled, with 11-12 pairs counted at the site this

year. Southern Power is continuing PG & E's voluntary monitoring program at the site (Collins, Pers. Comm.,1999). Since most nesting attempts at the Oakland Airport in the past few years have failed (probably due to predation by feral cats and the non-native red fox), the airport is no longer required to monitor terns or manage predators (Feeney, Pers. Comm.,1999).

Salt Marsh Yellow Throat

The salt marsh yellowthroat (*Geothlypis trichas sinuosa*), also known as the San Francisco yellowthroat, is a subspecies of the common yellowthroat. The salt marsh yellowthroat is hardly common,however, and is a state Species of Special Concern and a federal Species of Management Concern. Surveys in 1997 estimated 0.7 yellowthroats per hectare of marsh studied (or about 28 birds per 100 acres). Between 5,700 and 10,600 salt marsh yellowthroats may be breeding in available tidal marshes, and an additional unknown number in brackish and freshwater marshes. However, salt marsh yellowthroats were not common in marshes other than those in Suisun Bay; in some marshes, no yellowthroats were found.

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California Least Tern Nesting

Alameda Naval Air Station

Year	Maximum Number of Pairs	Maximum Number of fledglings
1976	10	NA
1977	45	NA
1978	80	13
1979	40	NA
1980	77	8
1981	74	103
1982	70	0
1983	3	1
1984	47	10
1985	53	60
1986	53	88
1987	59	97
1988	67	87
1989	75	93
1990	99	108
1991	112	144
1992	130	221
1993	128	210
1994	138	206
1995	150	73
1996	208	233
1997	244	316
1998	243	90

Salt Marsh Song Sparrows

The reproductive success of salt marsh song sparrows was lower in 1997 and 1998 than in 1996. In 1998, nest success (the probability that a nest fledges at least one young) was half of what it was in 1996, a trend of concern. Preliminary data for 1999 indicate continued low nesting success, with flooding the major cause of nest failure. Estimated numbers of Alameda song sparrows range from 3,700-8,100; for the Suisun song sparrow from 23,000-50,000; and for the Samuel's song sparrow from 20,000-44,000 (Nur, Pers. Comm., 1999). Both salt marsh song sparrow and salt marsh yellowthroat densities were greater in marshes with more channels, whether those channels were manmade or natural. While song sparrow density does not appear to be positively correlated with any one species of plant, yellowthroat densities were positively correlated with the percent cover of *Scirpus* (including bulrushes and tules), peppergrass, and cattails (Nur 1997).

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Peregrine Falcons

With the ban of DDT and extensive captive breeding efforts, the Bay's lost peregrine falcon population has begun to recover. Peregrine falcons commonly prey on ducks and waterbirds, and are thus a part of the estuarine food web. By the late 1980s and early 1990s, the Bay Bridge had two breeding pairs, and peregrines were wintering on all of the Bay bridges, even the Bay Bridge toll plaza. This year, there were confirmed nesting attempts on almost all of the bridges, meaning that at any given time, approximately 7 pairs of peregrines make the Estuary their home. The U.C. Santa Cruz Predatory Research Group has been removing young from the bridges when they begin to fledge to prevent them from drowning or being hit by cars (which often happens), and releasing them elsewhere around the state (Bell, Pers. Comm., 1999).

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Riparian Brush Rabbit

A subspecies of brush rabbit, the riparian brush rabbit (*Sylvilagus bachmani riparius*), is considered the most critically endangered species in the state, with less than a few dozen rabbits remaining. Endemic to California and weighing only 1.5 pounds, the rabbit was once common along the middle part of the San Joaquin River and tributaries, extending as far upstream as the riparian forests did. The remaining members of this subspecies are largely confined to Caswell State Park, along the San Joaquin, where 1997 floods probably lowered their already small numbers (Faubion; Pers. Comm., 1999 & Williams; Pers. Comm., 1999).

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Harbor Seals

Harbor seal (*Phoca vitulina*) numbers in the Bay have remained fairly stable over the past decade. Depending on the season—pupping, molting, or winter—they can be found in large numbers at one of three haul-out sites. During pupping season (March-May), harbor seals are most plentiful at Mowry Slough, where a high of 240 seals was counted during 1995-1997. In 1998, numbers dropped to 201. In the winter months, the seals are most plentiful at Yerba Buena Island, when Pacific herring (*Clupea pallasii*) are spawning in the Bay. In winter 1998, researchers counted 296 seals at Yerba Buena, slightly up from 1995's 242. Castro Rocks, a chain of rock clusters just south of the Richmond Bridge, is used year round, although more seals use the rocks during pupping and molting season (June-August). In the 1995 molting season, researchers counted 161 seals on the rocks. Numbers dropped over the next three years, reaching as few as 96, but by 1999 the count had rebounded to 141. Additional information is available for the Castro Rocks population, where researchers from San Francisco State University have been collecting baseline data for the past year and a half to help minimize impacts on the seals from seismic retrofit work scheduled for the Richmond Bridge in 2000. Harbor seals have been known to abandon a site if human disturbance is too great. (Green, Pers. Comm., 1999).

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Salt Marsh Harvest Mouse

The status of the Bay's endangered salt marsh harvest mice (*Reithrodontomys raviventris*) hasn't changed much over the past few years. Small and very small populations (a few mice per acre) can still be found in many locations around the Estuary in habitats that are marginal at best; the conversion of salt marsh to freshwater marsh in the South Bay poses a continuing problem for the mice (Shellhammer, Pers. Comm., 2000). In the North Bay at Suisun Marsh, mitigation for water project impacts requires state and federal agencies to conduct surveys of the salt marsh harvest mouse populations every three years. Seven set-aside areas in the marsh and the Peytonia Slough Ecological Reserve were surveyed during August and September 1998. The salt marsh harvest mouse appeared to have survived the extensive flooding of early 1998 while the western harvest mouse and house mouse did not. Trapping success was greatest at the Benicia Industrial unit, where 18 mice were captured in one month (Finrock, *IEP Newsletter* Fall 1998).

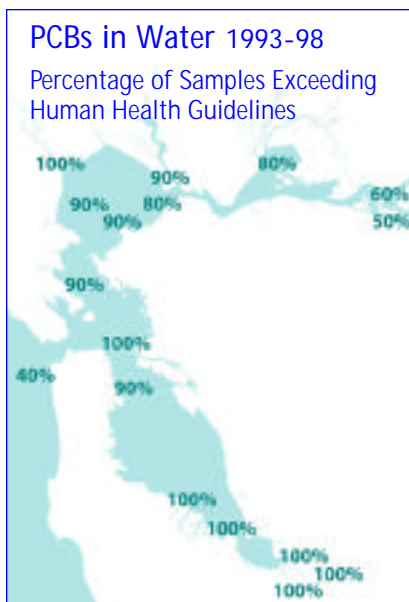
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WATER & SEDIMENTS

Overall Contaminant Conditions

The level of contamination in the Estuary today is high enough to impair the health of the ecosystem, even though some contaminants are clearly reduced from peak levels seen in earlier decades. As a whole, the Estuary can be described as moderately impaired. Indications of impairment include the toxicity of the water and sediment samples; the frequent presence of contaminant concentrations exceeding water, sediment and fish guidelines; and altered communities of sediment dwelling organisms. Overall, sites in the lower South Bay, the Petaluma River mouth, and San Pablo Bay are more contaminated than other sites. Contamination in the Central Bay is lower primarily due to mixing with relatively clean ocean water. Of all the contaminants measured by the Bay's Regional Monitoring Program, results suggest that those of greatest concern are mercury, polychlorinated biphenyls (PCBs), diazinon and chlorpyrifos (two pesticides). Also of concern are copper, nickel, zinc, DDT, chlordane, dieldrin, dioxins and polyaromatic hydrocarbons (PAHs). Work outside the RMP suggests that selenium is also a big concern (RMP, 2000).

► MORE INFO? www.sfei.org



Source: RMP

Harmful Chemicals in Estuary Fish

Estuary fish contain several types of contaminants at levels high enough to raise concern for the health of both the humans and wildlife consuming them, and even for the health of the fish themselves. Fish contamination guidelines referred to as "screening values" have been developed for the Estuary by the S.F. Estuary Institute's

Regional Monitoring Program following the guidance of the U.S. EPA (exceedance of the values indicates potential human health concerns). In 1997, mercury and PCBs exceeded screening values for over 50% of the samples tested from the Bay. Researchers also tested a small number of fish samples for dioxins, and all seven of these samples exceeded the dioxin screening value. Screening values for DDTs, chlordanes, and dieldrin were exceeded in 15-37% of samples tested. Organic contaminants such as PCBs and pesticides were highest in white croaker and shiner surfperch, while mercury was highest in striped bass and leopard shark. Fish from the Oakland harbor contained significantly higher contaminant concentrations than those from other locations.

Throughout the Bay, concentrations of PCBs, chlordane, dieldrin and DDT were lower in 1997 than 1994. Continued monitoring will be required to establish whether the declines observed are real indications of declining masses of contaminants or due to variation in other factors (RMP, 2000). Farther upstream, the Sacramento River Watershed Program began monitoring fish contamination in the river in 1997. White catfish from the Sacramento River exhibited relatively high mercury concentrations. Rainbow trout from the northern Sacramento River had the lowest mercury concentrations among the species sampled, and relatively low concentrations of organic contaminants (Davis et al., SOE Poster, 1999).

► MORE INFO? www.sfei.org

Percent of Bay Samples Meeting Water Quality Objectives*

	1994	1995	1996	1997	1998
Chromium	94	91	93	85	82
Copper	83	85	88	90	97
Mercury	79	80	87	67	75
Nickel	83	83	85	81	84
Lead	96	94	96	90	92
Selenium	100	100	100	97	99
Zinc	96	98	99	92	92
PAHs	61	69	53	59	25
Diazinon	93	100	94	100	100
Dieldrin	80	96	94	55	87
Chlordanes	100	93	84	87	89
DDT	98	92	90	88	91
PCBs	7	13	8	19	20

* Bay data from Regional Monitoring Program, SFEI 2000. Data from 1998 are preliminary.

Toxic Hot Spots in Bay Sediments

Sediment quality screening of 127 sites in the Bay—conducted as part of the State Water Resources Control Board's Bay Protection and Toxic Cleanup Program—identified a number of sites as candidate toxic hot spots (see map). Screening involved the use of reference sites to establish toxicity thresholds, followed by laboratory toxicity tests, in which amphipods and sea urchin embryos were exposed to field-collected sediment samples. Researchers then revisited sites producing toxic samples for additional toxic-

ty testing, chemical analysis, and evaluation of infaunal benthic communities. Preliminary investigations of sources and causes of observed toxicity were undertaken at a few candidate sites, indicating increasing adverse biological effects associated with increasing sediment concentrations of numerous covarying chemicals, including pesticides, metals, PCBs, PAHs, hydrogen sulfide and ammonia. Results (TIE) implicated trace metals as probable causes of toxicity at two sites, one in the South Bay and one in Suisun Bay (Hunt et al., 1998). Many of the most highly polluted sites were located near urban creeks and storm drains. (Hunt et al., SOE Poster, 1999).

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Linking Pollutants to Biological Effects

The developed world has invested billions of dollars in waste treatment since the 1970s, however, changes in ecological or biological responses are rarely associated with reductions in metal pollutants. Researchers examined this association in a novel, 23 year, time series of environmental change from a San Francisco Bay mudflat located 1 km from the discharge of a suburban domestic sewage treatment plant. Samples of surface sediment, the bioindicator clam *Macoma balthica* (which feeds on material attached to sediments), and metals loading data were used to establish links between discharge, bioaccumulation, and effects. Mean annual silver concentrations in *M. balthica* were 106 parts per million (ppm) in 1978 and 3.67 ppm in 1998. Concentrations of copper declined from 287 ppm in 1980 to a minimum of 24 ppm in 1991. Declining copper bioaccumulation was strongly correlated with decreasing copper loads from the plant between 1977-98. Relationships with bioaccumulation and total annual precipitation suggested inputs from non-point sources were most important in controlling zinc bioavailability during the same period. Reproduction of *M. balthica* in this metals-enriched environment persistently failed between the mid-1970s and mid-1980s, but recovered after metal contamination declined. Other potential environmental causes such as food avail-



ability, sediment chemistry or seasonal salinity fluctuations were not related to the timing of the change in reproductive capability. The results establish an associative link suggesting it is important to further investigate the chemical interference of copper and/or silver with invertebrate reproduction at relatively moderate levels of environmental contamination (Hornberger et al., SOE Poster, 1999).

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Contaminants in Coots

Though research shows that Bay Area water birds with diets high in animal foods are exposed to potentially health impairing trace elements, those with herbivorous diets have been less thoroughly examined. Researchers measured the concentrations of trace elements in the livers and the esophageal contents of an herbivorous water bird, the American coot (*Fulica americana*) to compare levels of contaminant exposure among different locations in the Bay system and with other water birds. They collected a total of 39 coots from four sites: Napa River and Mare Island Strait in the north, Berkeley in the middle, and Coyote Creek in the south. Livers of Berkeley samples differed significantly from those of Napa River and Mare Island Strait by their greater concentrations of arsenic and boron and lower concentrations of copper, but they seemed to be within normal ranges for birds. Otherwise the concentrations of trace elements in the livers did not differ among sites. Ingesta samples from Berkeley differed from the other sites because they tended to be higher in aluminum, vanadium, and zinc. In contrast to waterfowl, livers from the herbivorous coots in San Francisco Bay showed little exposure to cadmium, mercury, lead or selenium. Coot ingesta showed few samples with measurable levels of cadmium, mercury or selenium and had low levels of lead. The herbivorous diet of coots may shield them from exposure to such elements. However, high levels of vanadium were present in coot livers and ingesta from all four sites, suggesting adaptation to this known toxin (Hui, SOE Poster, 1999).

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For further information on contaminants, particularly issues related to habitat restoration, see pp. 56-59.